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(56) Documents cited
GB 1433590 A GB 1373644 A EP 0221475 A2
US 4210871 A US 3934204 A

(58) Field of search
UK CL (Edition K) H4L LDDRCP LDDRCW LDDRCX LDDRQ
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(54) Diversity antenna system

(57) A diversity antenna system is described which combines the signals (21, 22, etc.) of a number of antenna elements (1, 2, etc.) - that may have different positions and/or polarisations and/or radiation patterns - with weightings dependent on their respective signal levels. The combination process is performed at baseband, after demodulation, by means of a separate receiver (31, 32, etc.) and variable-gain amplifier (51, 52, etc.) for each antenna element. The gain setting of each variable-gain amplifier is adjusted in proportion to the signal level present at each receiver (31, 32, etc.) by the use of an open-loop control technique which responds swiftly and accurately to changes in signal level in order to counter the effects of signal fading due, for example, to multipath fading.

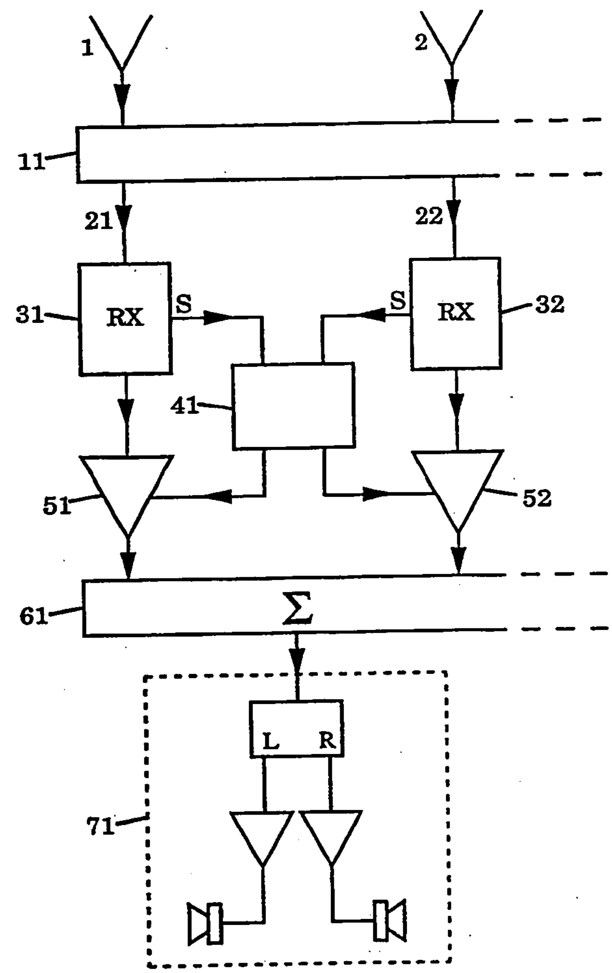

Figure 1

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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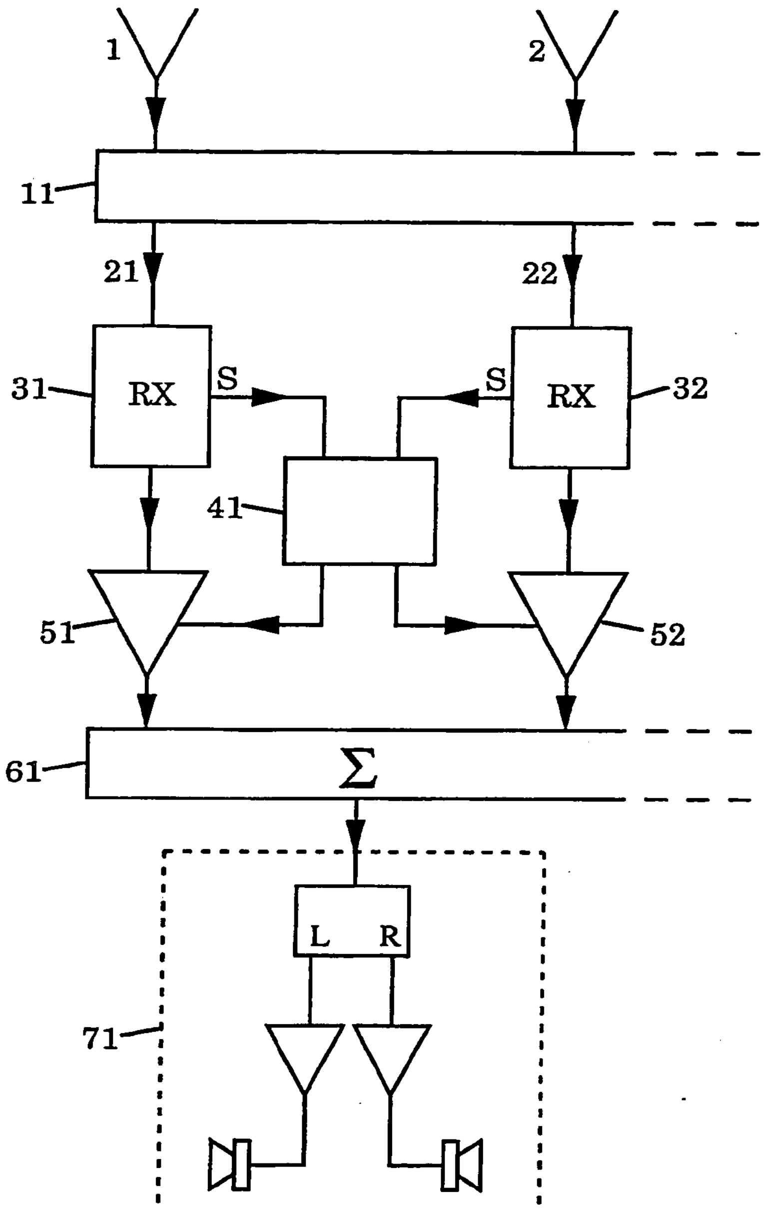

Figure 1

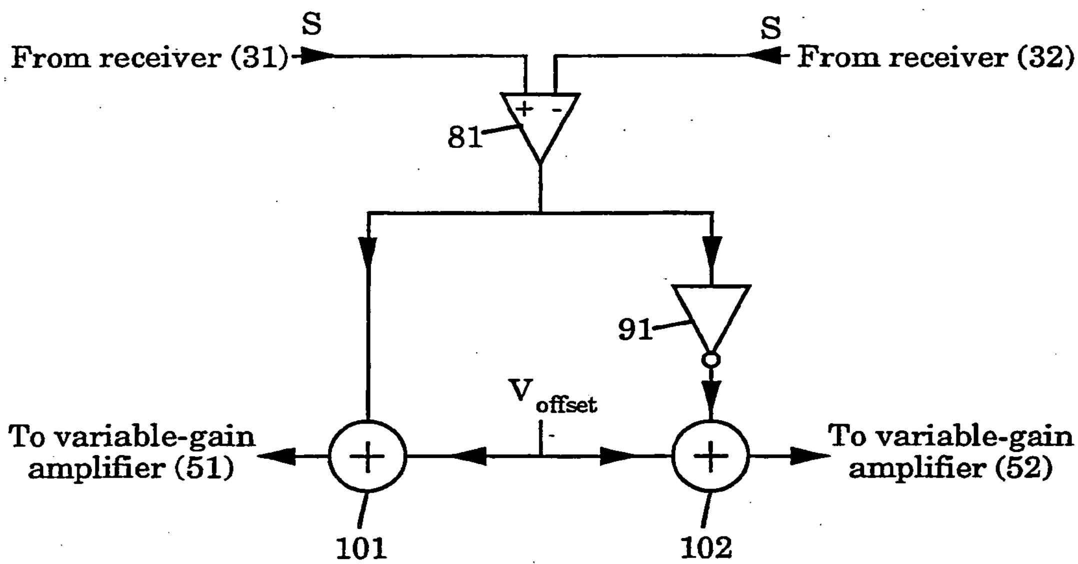
S
From receiver (31)
S
From receiver (32)
+
-
81
91
V offset
To variable-gain amplifier (51)
To variable-gain amplifier (52)
101
102

Figure 2

DIVERSITY ANTENNA SYSTEM

This invention relates to a type of diversity antenna system.

Diversity antenna systems are well known and consist of a number of antennas with different spatial locations and/or polarisations and/or radiation patterns, one of which may be selected - by means of a switching process - at any given time. The antenna system is used in conjunction with a receiver and the switching process is usually controlled by means of a closed-loop feedback system so as to obtain best performance under varying signal conditions. A particular application is to reduce the effects of multipath fading in mobile radio receivers.

Although offering improved performance they suffer from a number of problems: there is audible noise generation during switch-over between antennas, maximum use is not made of the signals available from all antennas and the control loop is prone to erratic behaviour under rapidly varying signal conditions.

According to the present invention, a means is provided to combine the contributions of each antenna with a weighting dependent on the respective signal strength present at each antenna element, the combination process being performed at baseband by means of a separate receiver and variable-gain amplifier for each antenna. The control process is entirely open-loop and with a response time rapid enough to react to the fastest likely rate of signal fading.

A specific embodiment of the invention will now be described by way of example with reference to the accompanying diagrams in which:

Figure 1 shows a block diagram of the complete system in the case of a two-element configuration;

Figure 2 illustrates a possible implementation of the control hardware.

Referring to figure 1, a number of antenna elements (1, 2, etc.) are connected to a signal distribution matrix (11) the outputs of which consist of a fixed combination of the said antenna signals. The signal distribution matrix is particularly likely to be used in the case of a single antenna structure having a diversity of radiation patterns and/or polarisations and may be omitted in the case of a system employing spatial diversity where the antenna signals may be directly fed to the

next stage of the block diagram. The plurality of signals (21, 22, etc.), again shown to be two by way of example in this description, are each provided as inputs to separate, individual receivers (31, 32, etc). The baseband outputs of each receiver (i.e. after demodulation) are virtually in-phase with each other and are each applied to separate variable-gain amplifiers (51, 52, etc.) the gains of which are adjusted by a common control system (41) in response to the signal level indications, "S", of each receiver. The outputs of each variable-gain amplifier are then combined in a common signal combiner (61), the output of which is fed to the common audio chain (71) thus producing an audio output. The technique is equally applicable to the reception of digital signals where (71) would be a digital interface. The proportionally varying nature of the contributions of each antenna signal enables the system to be completely noise-free in operation and enables full use to be made of the signals of each antenna. The open-loop nature of the control system (41) allows accurate and rapid adjustment of the variable-gain amplifiers (51, 52, etc) under the most hostile signal conditions - such as severe fast multipath fading. Functionally, the system is virtually identical to a phased array employing RF phase shifters and RF amplitude weights with closed-loop feedback control to achieve maximum signal-to-noise ratio; the present invention, however, requires neither RF phase shifters, nor RF amplitude weights, nor closed-loop feedback control.

For many applications, particularly audio, the control system (41) should operate in such a fashion that the resultant signal level leaving the signal combiner (61) is constant, irrespective of the varying gain settings of the variable-gain amplifiers. In applications where the baseband signal level derived from each receiver (31, 32, etc.) is constant regardless of the RF signal level at the input of said receiver - such as with FM receivers employing limiting - the sum of the gains of each variable-gain amplifier should be constant. Using the commonly known fact that maximum signal-to-noise performance is achieved by employing amplifier weightings in direct proportion to the signal strength present at each respective receiver, the required gains of (51) and (52) are

$$G_{51} = \frac{KV_1}{V_1 + V_2} \text{ and } G_{52} = \frac{KV_2}{V_1 + V_2}$$

where V_1 is the RF signal voltage detected at receiver (31), V_2 is the RF signal voltage detected at receiver (32) and K is an arbitrary constant.

A close approximation to these functions may be realised by means of the method shown in figure 2 which allows for simpler control circuitry. Signal level indications proportional to the logarithm of the RF signal voltages, which are easily and commonly realised in receiver design, are applied as inputs to a differential amplifier (81). The resulting control signal is proportional to the logarithm of V_1/V_2 and is applied directly to a summing node (101) and via an inverting amplifier (91) to a summing node (102) to increase the gain of the variable-gain amplifier (51) whilst decreasing the gain of the variable-gain amplifier (52), a DC offset being introduced at the summing nodes to set the gains of the variable-gain amplifiers (51, 52, etc.) at the centre of their operating range. The gains of (51) and (52) are now of the form

$$G_{51} = K\frac{1+\frac{20\log_{10}(V_1/V_2)}{A(dB)}}{2} \text{ and } G_{52} = K\frac{1+\frac{20\log_{10}(V_1/V_2)}{A(dB)}}{2}$$

and if the constant, A, is suitably chosen (such as 20 dB), these expressions are a close approximation to the previous equations. These two algorithms are shown by way of example; many other types of algorithm may also be implemented within the control system (41).

CLAIMS

1. A diversity antenna system comprising a number of antenna elements, with an optional signal distribution matrix, providing a plurality of signals each of which is received and demodulated by a separate receiver, the baseband output signals of which are each combined via separate variable-gain amplifiers with gain weightings dependent on the instantaneous signal level detected by the respective receiver.

2. A diversity antenna system, as claimed in claim 1, with proportional control of the weightings of each of the signals derived from the antenna elements in response to their respective signal levels.

3. A diversity antenna system, as claimed in claims 1 & 2, capable of including the contributions of all signals derived from the antenna elements to maximise the baseband signal-to-noise ratio.

4. A diversity antenna system, as claimed in claims 1 & 2, with open-loop control of the weightings of each variable-gain amplifier in such a fashion that the system may respond rapidly and accurately to changes in signal conditions whilst maintaining optimum amplifier weightings and maintaining constant baseband (audio) level.

5. A diversity antenna system, as claimed in claims 1, 2 & 4, where, in the case of a two-element design, a close approximation to optimum signal-to-noise weighting may be obtained by increasing the weighting of one element whilst decreasing the weighting of the other in proportion to the difference between the logarithms of the signal levels as detected by the respective receivers.

6. A diversity antenna system substantially as described herein with reference to figures 1 & 2 of the accompanying diagrams.

Amendments to the claims have b en filed as follows :

1. A diversity antenna system comprising a number of antenna elements, with an optional signal distribution matrix, providing a number of signals each of which is received and demodulated by a separate receiver, the baseband output signals of which are each combined via separate variable-gain amplifiers with gain weightings dependent on the instantaneous RF signal levels detected by the respective receiver.

2. A diversity antenna system, as claimed in claim 1, where - in the case of a two-element design - the ratio of the detected instantaneous RF signal strengths is used to adjust the baseband variable gain amplifiers in such a fashion that as the gain of one amplifier increases so the gain of the other decreases, the total gain remaining constant, thus ensuring that the baseband signal strength at the final output of the diversity receiver remains constant irrespective of the variation in relative RF signal strengths present at the two receivers.

3. A diversity antenna system, as claimed in claims 1 & 2, without requiring any phase compensation, RF amplitude adjustment or closed-loop control, yet capable of maximising the baseband signal-to-noise ratio with performance similar to an ideal phased array with both phase and amplitude compensation.

4. A diversity antenna system, as claimed in claims 1 & 2, with open-loop control of the weightings of each variable-gain amplifier in such a fashion that the system may respond rapidly and accurately to changes in signal conditions whilst maintaining optimum amplifier weightings and maintaining constant baseband (audio) level.

5. A diversity antenna system, as claimed in claims 1, 2 & 4, where, in the case of a two-element design, a close approximation to optimum signal-to-noise weighting may be obtained by increasing the weighting of one element whilst decreasing the weighting of the other in proportion to the difference between the logarithms of the signal levels as detected by the respective receivers.

6. A diversity antenna system substantially as described herein with reference to figures 1 & 2 of the accompanying diagrams.

ıt nts Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

(i) UK Cl (Edition K) H4L (LDDRCP, LDDRCW, LDDRCX, LDDRQ)

(ii) Int Cl (Edition 5) HO4B 7/08

Search Examiner

N W HALL

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Date of Search

11 AUGUST 1992

Documents considered relevant following a search in respect of claims 1-6

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1373644	(MARCONI) whole document	1
X	GB 1433590	(CIT-ALCATEL) whole document	1
X	EP 0221475 A2	(TOSHIBA) see especially figure 1	1
X	US 4210871	(HILL) see especially figure 4	1
X	US 3934204	(HILL) see especially figure 8 column 13 lines 42-47	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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